

Claims

1. A phased array antenna system with variable electrical tilt and including an array (60) of antenna elements (60U1 to 60L[n]) characterised in that it incorporates:
 - a) a divider (44) for dividing a radio frequency (RF) carrier signal into first and second signals,
 - b) a variable phase shifter (46) for introducing a variable relative phase shift between the first and second signals,
 - c) a phase to power converter (50) for converting the relatively phase shifted first and second signals into signals whose powers are a function of the relative phase shift,
 - d) first and second power splitters (52, 54) for dividing the converted signals into at least two sets of divided signals, the total number of divided signals in the sets being at least equal to the number of antenna elements in the array,
 - e) power to phase converters (56) for combining pairs of divided signals from different power splitters to provide vector sum and difference components with appropriate phase for supply to respective pairs of antenna elements (e.g. 60U[n], 60L[n]) located at like distances with respect to an array centre (62).
2. A system according to Claim 1 characterised in that it has an odd number of antenna elements (E0 to E7L) comprising a central antenna element (E0) located centrally of each pair of like distant antenna elements (e.g. E7U, E7L).
3. A system according to Claim 2 characterised in that it includes a third power splitter (120) connected between the phase to power converter and one of the first and second power splitters (88a, 88b) and arranged to divert to the central antenna element (E0) a proportion of the power from the phase to power converter (82/86).
4. A system according to Claim 1 characterised in that the phase to power and power to phase converters (50, 56) are combinations of phase shifters (82) and quadrature hybrid couplers (86).

5. A system according to Claim 1 characterised in that the phase to power and power to phase converters are combinations of phase shifters and 180 degree hybrid couplers.
6. A system according to Claim 1 characterised in that the divider (144), phase shifter (146), phase to power and power to phase converters (150, 156) and power splitters (152, 154) are co-located with the array (160) of antenna elements as an antenna assembly (144), and the assembly (144) has a single RF input power feed (165) from a remote source.
7. A system according to Claim 1 characterised in that the divider (e.g. 244T1) and phase shifter (e.g. 246T1A) are located remotely from the phase to power and power to phase converters, the power splitters (collectively 215) and the array (205) of antenna elements which are co-located as an antenna assembly, and the assembly has dual RF input power feeds (213A, 213B) from a remote source.
8. A system according to Claim 7 characterised in that the divider (e.g. 244T1) and phase shifter (e.g. 246T1A) are co-located with the remote source for use by an operator (201, 202) in varying angle of electrical tilt.
9. A system according to Claim 7 characterised in that it includes duplexers (211A, 211B) to combine signals passing from or divide signals passing to different operators (201, 202) which share the antenna system (200).
10. A system according to Claim 1 characterised in that the power splitters (52, 54) are arranged to provide for the antenna elements (e.g. 60U1) to receive drive voltages which fall from a maximum centrally of the antenna array (60) to a minimum at array ends (60U[n], 60L[n]).
11. A system according to Claim 1 characterised in that one power splitter (54) is arranged to provide a set of voltages which rise from a minimum to a maximum associated with the antenna array centre and its ends respectively, as appropriate to establish a progressive phase front across the antenna array, the phase front being substantially linear as an angle of tilt is increased in a working range of tilt, as required for reasonable boresight gain and side lobe suppression.

12. A method of providing variable electrical tilt in a phased array antenna system (40) including an array (60) of antenna elements (e.g. 60U1) characterised in that the method incorporates the steps of:
- dividing a radio frequency (RF) carrier signal into first and second signals,
 - introducing a variable relative phase shift between the first and second signals,
 - converting the relatively phase shifted first and second signals into signals whose powers are a function of the relative phase shift,
 - using power splitters (52, 54) to divide the converted signals into at least two sets of divided signals, the total number of divided signals in the sets being at least equal to the number of antenna elements in the array,
 - combining pairs of divided signals from different power splitters (52, 54) to provide vector sum and difference components with appropriate phase and supplying the components to respective pairs of antenna elements located at like distances with respect to an array centre.
13. A method according to Claim 12 characterised in that the antenna array has an odd number of antenna elements (E0 to E7L) comprising a central antenna element (E0) located centrally of each pair of like distant antenna elements (e.g. E1U, E1L).
14. A method according to Claim 13 characterised in that the phased array antenna system includes a third power splitter (120) connected to receive one of the signals whose power is a function of the relative phase shift and the method includes using such splitter to divert to the central element (E0) a proportion of the power in such signal.
15. A method according to Claim 12 characterised in that conversion of the relatively phase shifted first and second signals and combining of pairs of divided signals are implemented respectively using phase to power and power to phase converters incorporating 90 or 180 degree hybrid couplers.
16. A method according to Claim 12 characterised in that steps a) to e) are implemented using components (144 to 158) co-located with the array (160) of antenna elements to form an antenna assembly with input from a single RF input power feed (165) from a remote source.

17. A method according to Claim 12 characterised in that steps a) and b) are implemented using components (e.g. 244T1, 246T1A) located remotely of the array (205) of antenna elements and steps c) to e) are implemented using components (215) co-located with the array (205) and forming therewith an antenna assembly having dual RF input power feeds (213A, 213B) from a remote source.
18. A method according to Claim 17 characterised in that step b) includes varying the relative phase shift to vary the angle of electrical tilt.
19. A method according to Claim 17 characterised in that it includes combining signals passing from or dividing signals passing to different operators (201, 202) which share the antenna system (200).
20. A method according to Claim 12 characterised in that it includes providing for the antenna elements to receive drive voltages which fall from a maximum centrally of the antenna array to a minimum at array ends.
21. A method according to Claim 12 characterised in that step d) includes providing for one set of divided signals to rise from a minimum to a maximum associated with the antenna array centre and its ends respectively, as appropriate to establish a progressive phase front across the antenna array, the phase front being substantially linear as an angle of tilt is increased in a working range of tilt, as required for reasonable boresight gain and side lobe suppression.